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FRENCH CREEK STUDY. REPORT ON LOW FLOW REQUIREMENTS IN FRENCH CREEK BELOW MEADVILLE, PENNSYLVANIA

Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

January 1959

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FRENCH CREEK STUDY

Report on Low Flow Requirements in French Creek below Meadville, Pennsylvania

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Pittsburgh District, Corps of Engineers,
U. S. Army, The Pennsylvania Department of Health,
and the City of Meadville, Pennsylvania

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Division of Sanitary Engineering Services

Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

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PURPOSE AND OBJECTIVES

In November, 1954 the District Engineer, Pittsburgh District, Corps of Engineers, U. S. Army, requested the Public Health Service to prepare an evaluation of low-flow regulation requirements in French Creek, Allegheny River Basin, with respect to pollution abatement and industrial and municipal water supply. An evaluation was prepared in January, 1955 employing available existing data. It was concluded by the Public Health Service that the most important pollution problem occurs in the vicinity of Meadville, Pennsylvania and that, under adverse low-flow conditions, dissolved oxygen concentrations in the stream below Meadville might fall below desirable objectives. Existing data were not considered sufficient to justify definite conclusions regarding low-flow augmentation necessary to protect water quality in the stream. Supplemental stream and waste surveys were recommended to provide the data necessary for a comprehensive analysis of the problem.

In August, 1955 the U. S. Public Health Service, the Pennsylvania Department of Health, the City of Meadville, Pennsylvania, and the Corps of Engineers, U. S. Army, cooperated in a survey on French Creek in order to obtain the data necessary for a detailed analysis of the problem.

Principal objectives of the Survey were as follows:

1. To determine the present chemical, physical, and biological quality of the stream.

2. To determine the nature, volume, and strength of the major waste loads discharged to the stream in the Meadville area.

3. To estimate the deoxygenation and reoxygenation characteristics of the stream and thereby determine the ability of the stream to assimilate pollution loads.

4. To predict the effect of a future increase in waste load on the oxygen resources of the stream as a result of possible population increases and/or industrial expansion.

5. To determine minimum low-flow requirements needed to maintain a minimum daily average dissolved oxygen concentration of 5.0 ppm in the stream in the case of certain assumed future pollution loads.

SUMMARY AND CONCLUSIONS

1. Chemical, physical, and biological data obtained during the study provided no evidence of damages to water quality that might significantly affect the beneficial uses of the stream. Although stream flows during the survey were considerably greater than those that might be expected under drought conditions, analysis of the data indicated that the once in ten year daily low-flow should not result in critical dissolved oxygen conditions in the stream if the pollution loads were no greater than those observed during the survey.

2. There are three major sources of waste discharged to French Creek in the Meadville area. All of these provide a high degree of treatment before discharging their wastes to the stream. The American Viscose Corporation and the Meadville sewage treatment plant provide secondary treatment of organic wastes to such a degree that there was no significant degradation of the stream's oxygen resources during the survey. Talon, Inc., has successfully provided neutralization of low pH wastes, the acid effects of which could, under certain conditions, destroy aquatic life. In addition, this industry has successfully prevented the destruction of aquatic life by not allowing toxic materials such as cyanides, copper, chromium, and zinc compounds to enter the stream in critical amounts.

3. The effect of increased pollution loads on minimum dissolved oxygen concentrations is shown in the accompanying table. This table also shows the flows required to maintain a minimum average daily dissolved oxygen concentration of 5.0 ppm under various loading conditions. The "maximum" loadings in the table were designed to take into account conditions of treatment plant operation and waste discharges that might result in loads considerably higher than would be the case under average conditions. Conclusions regarding critical stream conditions must of necessity be based on maximum loading conditions.

Loading	Discharge of Meadville* (cfs)	Minimum** DO (ppm)	Estimated flow required to maintain a minimum critical DO of 5.0 ppm** (cfs)
Average Present	35	6.2	< 35
	50	6.3	
Maximum Present	35	4.8	40
	50	5.2	
Maximum Present plus 25%	35	4.2	60
	50	4.7	
	75	5.5	
Maximum Present plus 50%	35	3.5	
	50	4.3	70
	75	5.2	

* Mead Avenue Bridge

** Average daily value

4. To safeguard the oxygen and aquatic life resources of French Creek, a high degree of treatment will continue to be required before wastes are discharged to the stream. Particular care should be exercised to assure that the extremely toxic potential of certain of these wastes is not realized.

GENERAL DESCRIPTION

French Creek originates in Chatauqua County, New York and flows southwesterly into Erie County, Pennsylvania. It passes into Crawford County, then southeasterly through Mercer County, and Venango County to its mouth on the Allegheny River at Franklin, Pennsylvania. The total drainage area of the French Creek Basin is 1,246 square miles. This region has a mean annual rainfall of about 35 inches and a mean annual temperature of about 50°F.

French Creek is used as a source of municipal water supply by the cities of Cambridge Springs and Franklin and as a source of industrial water supply at Franklin. The municipal water supply at Meadville and industrial supplies in the area are obtained from wells penetrating an aquifer some 30 to 60 feet below the valley floor. In the Meadville area, total municipal water usage is about 2.1 mgd and total industrial water usage is about 6.5 mgd.

French Creek is used extensively for recreation, including fishing, boating, and bathing. There are many cottages located along the stream from its mouth up to Cambridge Springs, with particularly heavy concentrations occurring in the Cochranton area below Meadville and from Saegertown upstream to Cambridge Springs.

In addition to the other beneficial uses outlined above, French Creek is also used as a carrier for the disposal of both sanitary sewage and industrial waste treatment plant effluents. The major sources of pollution are located at Meadville, Pennsylvania which is about 31 miles above the confluence of French Creek with the Allegheny River at Franklin. The drainage area tributary to French Creek at Meadville is about 790 square miles. Lesser sources of pollution, tributary directly to French Creek, are located at Saegertown (mile 38, drainage area 621 square miles) and Cambridge Springs (mile 49, drainage area 470 square miles). Wastes from the Union City area are discharged to the south branch of French Creek near its confluence with the main stream at about mile 71. In order that the use of the creek as a waste carrier not interfere with its other uses, a high

degree of waste treatment has been required by the Sanitary Water Board of the Pennsylvania Department of Health before domestic and industrial wastes are discharged to French Creek.

FIELD SURVEY ORGANIZATION AND METHODS

A preliminary field reconnaissance was conducted on August 4 and 5, 1955. Sampling was initiated on Monday, August 8, 1955, and was continued through August 19, 1955. On August 8, 9, 10, 15, and 16, samples were collected once daily from all stream stations and eight-hour composites were collected from the major sources of pollution. Around-the-clock sampling was performed at selected stream stations on August 11-12 and August 17-18. Waste samples were also collected during these periods. Sampling was completed on August 19, 1955 and all analytical work was completed on August 23, 1955.

In addition to regular sampling, special samples were taken for the following purposes:

1. Stream samples for determination of river deoxygenation rates.

2. Stream samples for biological study.

3. Waste samples for bioassay.

Stream Survey

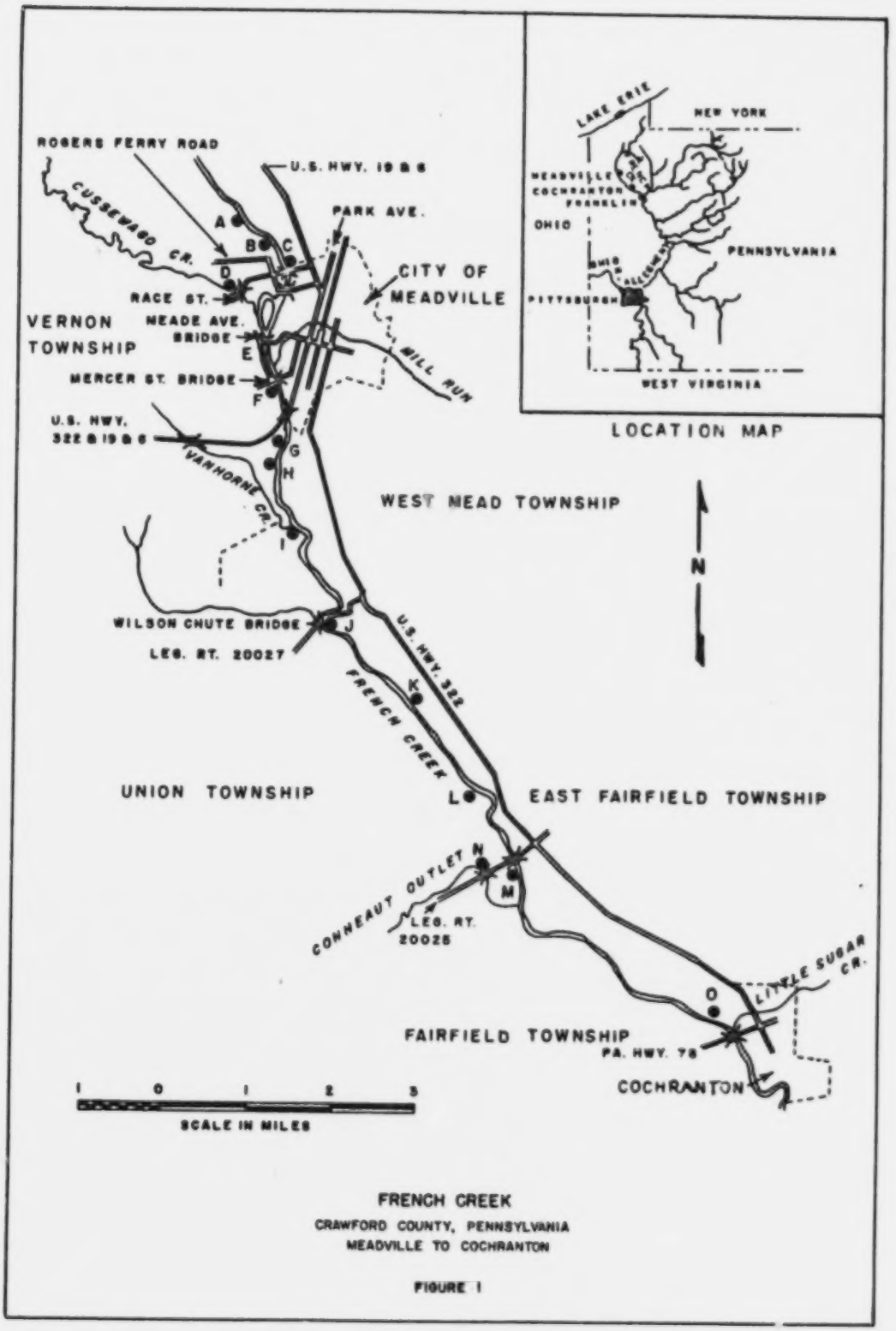
Sampling Stations

Sampling stations were selected on French Creek, covering a 14.2 mile reach from above Meadville (upstream from the American Viscose Corp.) to a point just above the confluence of Little Sugar Creek and French Creek at Cochranton (Fig. 1). In addition, a regular sampling station was established on Cussewago Creek, which is tributary to French Creek at Meadville. A list of sampling station designations and locations is presented in Table 1.

Table 1

Stream Sampling Stations

Station	Location	Miles from Station A
A	Above American Viscose Corp.	0
B	Below American Viscose Corp.	0.7
C	Race St. Bridge over French Creek, Meadville	1.1
D	Cussewago Cr. - at Race St. Bridge, Meadville	-
-	Cussewago Creek enters French Creek	1.5
E	Mead Ave. Br. over French Cr., Meadville	1.8
F	Mercer St. Br. over French Cr., Meadville	2.2
G	Above sewage treatment plant and Talon, Inc.	2.6
H	Below sewage treatment plant and Talon, Inc.	3.4
I	----------	4.9
J	Wilson Chute Br. over French Cr. on Leg. Rt. 20027	6.5
K	----------	7.9
L	Shaw's Landing	9.6
M	Bridge over French Cr. on Leg. Rt. 20025, (at Wilkie's Camp)	10.6
-	Conneaut Outlet enters French Cr.	11.2
N	Conneaut Outlet, bridge near mouth	-
O	Cochranton above Little Sugar Cr.	14.2



FRENCH CREEK
CRAWFORD COUNTY, PENNSYLVANIA
MEADVILLE TO COCHRANTON

FIGURE 1

Sampling Procedure

DO (dissolved oxygen) samples were collected at about mid-depth at the quarter points of the river cross-section at each station, and the three individually determined results averaged for the DO value at the station. Samples for other determinations were prepared by compositing equal portions from each of the quarter point samples. River water temperatures were taken at each quarter point.

Daily sampling runs were conducted on August 8, 9, 10, 15, and 16, 1955. Samples were collected once daily at each of the thirteen stations on French Creek and at the Cussewago Creek station. Around-the-clock sampling was conducted on August 11-12, and August 17-18. Samples were collected every four hours at the following selected stations: Station A, C, H, J, M, and O.

Analyses Performed

Analyses performed on stream samples are presented in Table 2. This table represents routine analyses performed during the survey.

Waste Surveys

The three major waste discharges in the Meadville area were sampled during the survey. The American Viscose Corporation is engaged in the production of acetate yarn. The principal wastes from this plant are sanitary sewage and wastes from the manufacture of acetate flake. Both wastes receive secondary treatment and are discharged to French Creek through the "Mill Waste Outlet" (lower outfall). There are two other outfalls discharging to French Creek from this plant, the No. 1 storm sewer (middle outfall) and the upper storm sewer (upper outfall). The discharges from both storm sewers are composed primarily of roof drainage and cooling water. The three outfalls were sampled regularly during the survey. During the daily sampling runs on August 8, 9, 10, 15, and 16, a composite sample was collected at each outfall. Each composite sample consisted of an equal portion collected every two hours over an eight-hour period. During around-the-clock sampling, a 24-hour composite sample was collected at each outfall consisting of an equal portion collected every four hours. Since BOD's were to be run on these samples, they were iced during the compositing period. Discharge data for the lower outfall were provided by the industry. The discharges from the other two outfalls are not routinely measured by the company and discharge data were not obtained for them. It later became necessary, however, to estimate discharge from the upper outfall. A schedule of routine analyses performed on wastes from the American Viscose Corp. is presented in Table 3.

Table 2

Analyses Performed on Stream Samples

Sta.	pH	Alk.	DO	BOD	Susp. Solids	NO_3	NO_2	PO_4	CN
A	xxx	xxx	xxx	xxx	x	xx	✓	✓	✓
B	x	x	x	x	x	-	-	-	-
C	xxx	xxx	xxx	xx	-	-	✓	-	✓
D	x	x	x	x	x	-	-	-	-
E	x	x	x	-	-	-	-	-	-
F	x	x	x	-	-	-	-	-	-
G	x	x	x	x	x	-	✓	-	-
H	xxx	x	xxx	xxx	x	xx	✓	✓	✓
I	x	x	x	-	-	-	-	-	-
J	xxx	x	xxx	xxx	x	-	✓	-	-
K	x	x	x	-	-	-	-	-	-
L	x	x	x	-	-	-	-	-	-
M	xxx	x	xxx	xxx	x	-	✓	-	-
O	xxx	x	xxx	xxx	x	-	✓	-	✓

x - performed on daily samples only
xx - " " 24 hour " "
xxx - " " both daily & 24 hr. samples
✓ - " " selected samples for check purposes

Table 3

Analyses Performed on Waste Samples from the American Viscose Corp.

	pH	Alk.	BOD	NO_3	PO_4
Upper outfall	xx	x	xx	x	x
Middle outfall	xx	x	xx	x	x
Lower outfall	xx	x	xx	x	x

x - performed on daily samples only
xx - performed on both daily and 24-hour samples

Talon, Inc. (the other major source of industrial pollution) produces wastes including cyanides and cyanide rinse water from plating operations and acids, caustics, bichromates, oils, soaps, etc., from pickling and other metal finishing processes. Cyanide and acid wastes are given separate batch treatment and then discharged to French Creek. Samples of the treated wastes discharged from this plant were collected by the industry and furnished to the field laboratory for analysis. Only those batches discharged during stream survey periods were routinely sampled. A complete record of all discharges to French Creek during the period August 8-19 inclusive was furnished by the plant. This record included the plant batch number, the times of discharge, total volume discharged, and the rate of discharge for each batch.

A schedule of routine analyses performed on the wastes from this plant is presented in Table 4.

Table 4

Analyses Performed on Waste Samples from Talon, Inc.

Type of Waste	pH	Alk.	BOD	CN	Cr	Cu	Zn
Acid	x	x	x	-	x	x	x
Cyanide	x	x	x	x	x	x	x

x - performed on daily samples

The sewage treatment plant operated by the City of Meadville provides complete treatment (activated sludge) for the sanitary wastes from a city of 19,000 (1950 population 18,972). During the winter months (when flow in the creek is not critical and recreational use of the stream is negligible) primary treatment alone is provided. The effluent from the sewage plant was sampled regularly during the survey. During the daily sampling on August 8, 9, 10, 15, and 16, a composite sample was collected consisting of an equal portion collected every two hours over an eight-hour period. These composite samples were iced during the compositing period. During around-the-clock sampling, individual samples were taken and analyzed every three hours. Flow data were provided by the City of Meadville.

The following analyses were performed on samples from the sewage treatment plant:

BOD - all samples

NO_3 - all samples collected after August 12

NO_2 - all samples collected after August 12.

The results of pH and alkalinity determinations on the effluent were provided by the City of Meadville.

PRESENTATION AND ANALYSIS OF DATA

Hydrology

Stream Discharge Data

During the period August 3 - August 19, 1955, discharge measurements on French Creek and Cussawago Creek were carried out by personnel of the Corps of Engineers, U. S. Army. The results of those measurements are presented in Figures 2 and 3. These hydrographs illustrate a major source of difficulty in the analysis of stream data. During the first week of sampling (August 8 - August 12), the flow in French Creek was practically constant at 80 cfs. However, in the five days preceding August 8 the flow increased from a minimum of 30 cfs to a maximum of 100 cfs, and then decreased to 80 cfs on August 8. During a 24-hour period on the week-end of August 13-14, the flow increased from 80 cfs to 300 cfs, and then dropped gradually from August 15 - August 19, finally reaching 100 cfs.

Discharge measurements were made at the Mead Avenue Bridge (Sampling Station "E") in Meadville, where the city maintains a staff gage. Stream discharges at the other sampling stations were obtained by adjusting the Meadville discharge in proportion to the drainage area tributary to the station in question. The areas were determined from U.S.G.S. quadrangle maps by planimetering. From these data, drainage area factors were developed (assuming a factor of 1.00 at Station E) to facilitate computation. This information is presented in Table 5.

Time of Passage Study

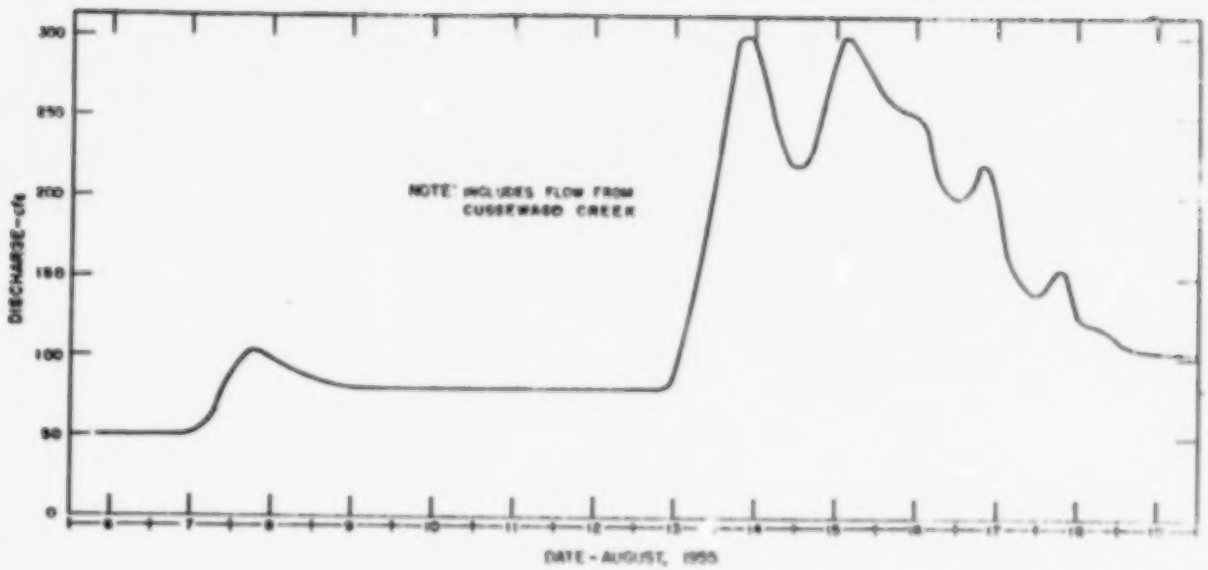
To facilitate the determination of time of passage, 81 stream cross-sections were measured on French Creek in the 11.6 mile reach between stations G and O. This was considered to be the critical area with respect to organic pollution. Sections were spaced so as to define each riffle and pool and consequently the distances between sections varied from about 100' in short riffles to as much as 2,300' in long, fairly uniform pools.

Times of flow in the reach between stations C and O were determined by volume displacement, according to the following formula:

$$t(\text{hours}) = \frac{A_{av} \times L}{3600\ Q}$$

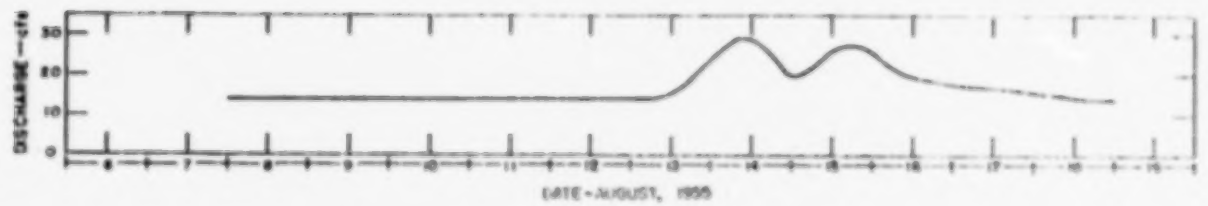
where: t = time of flow for the reach in hours
A_{av} = the average cross-sectional area of the reach in square feet
L = the length of the reach in feet
Q = the average discharge in the reach in cfs.

Results of the time of passage study are presented in Table 6 and Figure 4.



HYDROGRAPH - FRENCH CREEK AT MEADVILLE, PA, (MEAD AVENUE BRIDGE)

FIGURE 2



HYDROGRAPH - CUSSEWAGO CREEK AT MEADVILLE, PA.

FIGURE 3

Table 5

Drainage Areas and Area Factors

Station	Drainage Area (Sq. Mi.)	Area Factor
A	679	0.86
B	679	0.86
C	680	0.86
Cussawago Creek Enters	780	0.99
E (City of Meadville Gage)	790	1.00
F	791	1.00
G	791	1.00
H	792	1.00
I	801	1.01
J	809	1.02
K	811	1.03
L	815	1.03
M	817	1.03
Conneaut Outlet Enters	920	1.16
O	927	1.17
Utica, Pennsylvania*	1028	1.30

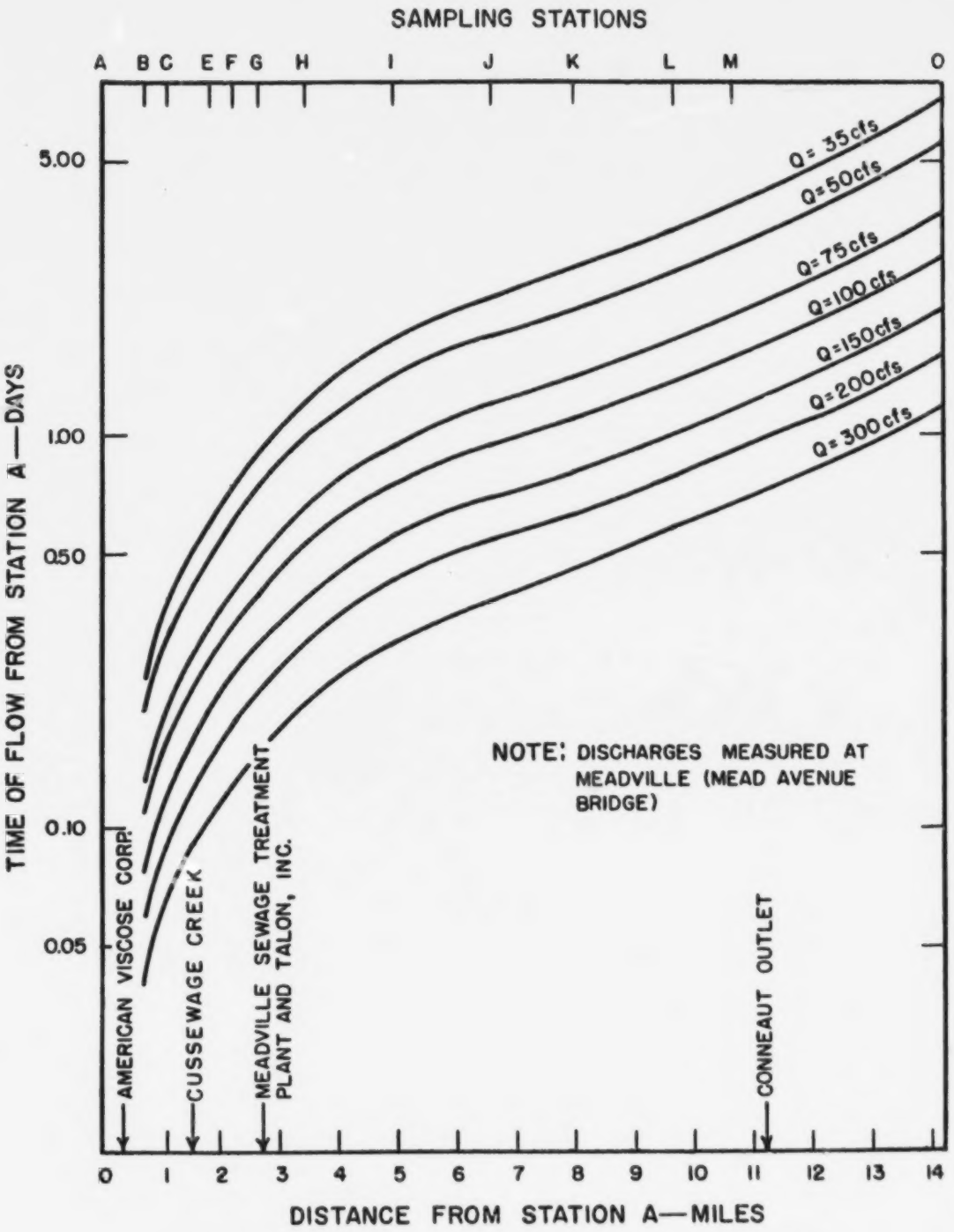
* U.S.G.S. Gaging Station

Table 6

Times of Flow - Days

Station	River Miles from Sta. A	Discharge at Station E(Q_E) - cfs						
		35	50	75	100	150	200	300
		Time of Flow - Days						
A *	0	0	0	0	0	0	0	0
B *	0.7	0.24	0.20	0.13	0.11	0.08	0.06	0.04
C *	1.1	0.38	0.31	0.21	0.17	0.12	0.09	0.07
Cussawago Creek *	1.5	0.51	0.42	0.28	0.23	0.17	0.13	0.09
E *	1.8	0.62	0.51	0.34	0.27	0.20	0.15	0.11
F *	2.2	0.75	0.62	0.41	0.33	0.25	0.19	0.13
G *	2.6	0.89	0.73	0.49	0.39	0.29	0.22	0.15
H	3.4	1.27	1.00	0.67	0.53	0.39	0.30	0.21
I	4.9	1.79	1.43	0.95	0.76	0.56	0.43	0.30
J	6.5	2.28	1.81	1.21	0.95	0.70	0.55	0.38
K	7.9	2.68	2.10	1.41	1.11	0.82	0.63	0.46
L	9.6	3.38	2.61	1.75	1.38	1.03	0.80	0.59
M	10.6	3.95	3.02	2.02	1.60	1.17	0.01	0.67
Conneaut Outlet	11.2	4.40	3.35	2.24	1.77	1.30	1.00	0.75
------	12.3	5.25	3.96	2.64	2.08	1.53	1.18	0.88
------	13.3	6.18	4.63	3.09	2.43	1.78	1.37	1.02
O	14.2	7.66	5.68	3.79	2.97	2.15	1.65	1.22

* Estimated times of flow



TIME OF FLOW VS. DISTANCE FROM STATION A

FIGURE 4

Special Studies

Biological Observations

A biological reconnaissance was made from August 9 to 12, 1955, in an attempt to obtain qualitative information about aquatic life associations in French Creek. Conclusions reached herein are primarily based on general observations of macro-invertebrate bottom organisms. Some additional information relative to the aquatic life resources of French Creek was obtained from personnel of the Pennsylvania Fish Commission and from resident fishermen.

Throughout the reach of the stream studied, from Stations A through M, there occurred consistently a variety of bottom organisms that collectively represented a clean water association. Organisms observed included caddisflies, stoneflies, mayflies, gill-breathing snails, unionidae clams, and crayfish. Individuals of such associations were denied access to restricted areas of the stream bottom at certain stations because of inimical conditions caused by construction work. Pollution tolerant associations represented by certain blood worms, sewage worms, rat-tailed maggots, etc., were not present as entities at any of the stations.

Construction operations at Stations A, B, and C had temporarily made limited bottom areas an unsuitable habitat for clean water associations of bottom organisms. Dredging operations at Station B resulted in a paucity, along the left bank, of the clean water organisms listed above, but did not exclude them from most of the general station area. Absence of such organisms from an area where the bottom has been disturbed can be attributed to removal of the substrate and to the smothering effect of settling silt resulting from such an operation. Similar effects were reflected in the absence of clean water organism associations, in restricted areas, as a result of pipe line construction at Station A and bridge work at Station C.

Fishing activity was observed on French Creek on each of the days of the biological reconnaissance. Downstream from Station G and about 200 yards below the Meadville Sewage Treatment Plant and Talon, Inc. outfalls, walleyes, carp, and schools of unidentified minnows were observed. Fishermen in this area reported having taken walleyes, smallmouth black bass, chubs, and carp.

At Station J, fishermen reported having taken smallmouth black bass and walleyes. Shiner minnows were observed to be abundant in this area.

At Station M, residents of the area indicated that a variety of fish are taken from year to year, including walleyes, catfish, black bass, muskellunge, sunfish, suckers, and carp.

Fish taken at Station O were reported by residents of the area to include large and smallmouth black bass, walleyes, muskellunge, various sunfish and bullheads.

Data assembled March 7, 1956 by the Fisheries Research Laboratory of the Pennsylvania Fish Commission indicate that no intensive study has been made of the fisheries resources of the portion of French Creek covered by this report. Table 7 contains information received from the Fish Commission illustrating stocking activities carried on over a number of years covering the 41-mile reach of French Creek in Crawford County which includes the portion of the stream covered by this report.

To safeguard the aquatic life resources of French Creek and provide for future industrial and municipal expansion, a high degree of waste treatment will continue to be required. Adequacy of secondary treatment of organic wastes by the American Viscose Corp. and by the municipal sewage treatment plant, with no apparent degradation of the stream's oxygen resources, is attested to by the occurrence of clean water aquatic life associations at downstream stations. That wastes with an extremely toxic potential can be treated and discharged without apparent detriment to aquatic life is demonstrated by Talon, Inc.

Results of Bioassays on Talon, Inc. Wastes

Bioassays were performed on representative samples of treated acid and cyanide wastes from Talon, Inc. by the Bioassay Application Unit of the Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio. The bioassays were conducted using fathead minnows (Pimephales promelas) as the test fish. Several waste concentrations were tested using both hard and soft dilution waters which had the following characteristics:

Hard Water		Soft Water	
pH	= 8.2	pH	= 7.4
Alkalinity	= 360 ppm	Alkalinity	= 18 ppm
Hardness	= 400 ppm	Hardness	= 20 ppm

Four fathead minnows were introduced into four liters of each waste concentration tested and observed for a total period of 96 hours. Ninety-six hour median tolerance limits (TL_m - i.e., the concentration

Table 7

Fish Stocking Records
French Cr., Crawford County, Pennsylvania

Kinds Stocked	Size	Number	Span of Years
Walleyes	Fry	3,397,000	1943-1955
	Adults (13" to 23")	666	
Bass "including a ⅘ of largemouth"	Fingerlings	51,149	1933-1955
	Adults (12" to 18")	550	
Brown Trout	Fingerlings, 2"	4,800	1937
Brook Trout	Fry	1,320,000	1936
	Fingerlings, 2"	2,300	
Bream	1" to 7"	21,380	1932-1953
Sunfish	½" to 7"	110,450	"
Catfish	3" to 12"	59,520	"
Suckers	Fry to 8"	996,950	"
Yellow Perch	Fry to 4"	15,280,000	"
Frog Tadpoles	--------	95,000	"

of waste which produces 50% mortality of the fish in 96 hours) were determined and recommended dilutions derived therefrom.(1)

The bioassay on the treated acid waste was performed on a sample collected on August 8, 1955. The sample was received in the laboratory on August 15, 1955 and the tests were begun immediately. Results of the test are as follows:

Concentration of Waste	Time of Exposure	Observations
100%	24 hours	One fish dead - three alive
	48 hours	One fish dead - three alive
	96 hours	One fish dead - three alive
32%	96 hours	All fish living in both hard and soft waters

96 hour TL_m => 100%

The bioassay on treated cyanide waste was performed on a sample collected August 23, 1955. The sample was received in the laboratory on August 26, 1955, and the tests were begun immediately. Results of the tests are as follows:

Type of Dilution Water	Concentration of Waste	Time of Exposure	Observations
	100%	1 hour	One fish dead
	100%	<16 hours	All fish dead
Soft	56%	96 hours	All fish alive
	32%	96 hours	All fish alive
	10%	96 hours	All fish alive

Type of Dilution Water	Concentration of Waste	Time of Exposure	Observations
Hard	56%	96 hours	All fish alive
	32%	96 hours	All fish alive
	10%	96 hours	All fish alive

96 hour TL_m = 75% for both hard and soft dilution waters.

It may therefore by concluded that conditions toxic to aquatic life would not be expected from discharge of the treated waste under minimum flow conditions.

The bioassay results, with 96 hours TL_m values of >100% (i.e., less than 50% fish mortality in 96 hours in the pure effluent) for the acid wastes and 75% for the cyanide wastes, indicate a very low degree of toxicity for these wastes. The fact that the toxicity was the same in two widely different dilution waters would make the results directly applicable to French Creek waters.

In order to relate the laboratory results to actual conditions, which include the possibility of longer exposure and the presence of more sensitive aquatic organisms, an application factor of ten is recommended. Thus, a dilution of 1:10 for the acid waste and 1:15 for the cyanide waste with stream water should produce safe conditions for aquatic life. As the maximum rate of discharge from Talon, Inc. is limited to 200 gpm (0.45 cfs) the wastes are diluted to 78 times their original volume at a stream flow of 35 cfs (the minimum daily flow expected on the average once in ten years), the basis for design set forth in the section on low flow frequencies. It may be concluded from the representative samples of the plant wastes tested during the survey period that conditions toxic to aquatic life would not be expected under minimum flow conditions.

However, the untreated plant wastes are known to contain high concentrations of chemicals (Cu, Cr, CN) which are extremely toxic to aquatic life. Bioassays with pure chemicals, conducted under the same conditions as the effluents, gave the following results:

Chemical	96 hour TL_m Hard Water	Soft Water
CN	0.35 ppm	0.23 ppm
Cr (hexavalent)	25.5 ppm	11.3 ppm
Cr (trivalent)	78 ppm	4.4 ppm
Cu	1.22 ppm	0.60 ppm

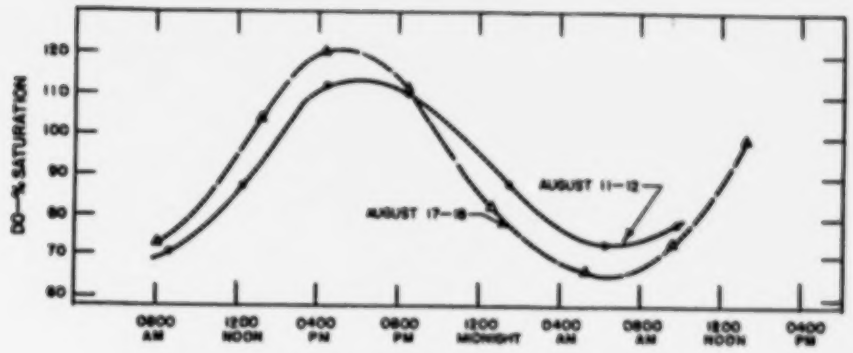
One tenth of the above values would be expected to be non-toxic to most forms of aquatic life. Based on data furnished by Talon, and the above tests, it is believed that even small quantities of the untreated wastes would be significantly harmful to aquatic life. Extreme care must be used to avoid the discharge of any untreated waste to French Creek.

Dissolved Oxygen and BOD Data

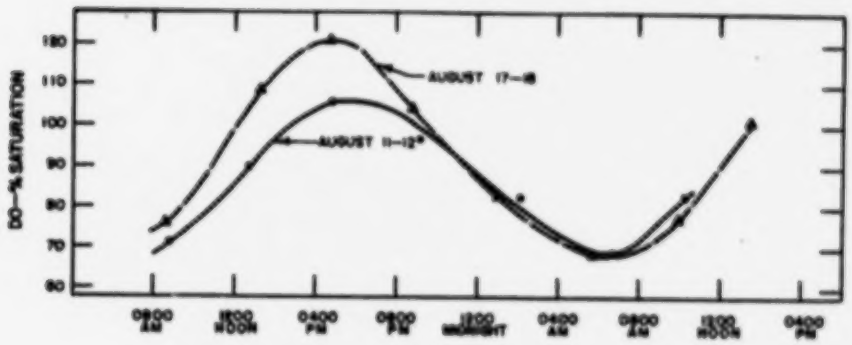
Stream Data

During the two 24-hour sampling periods on August 11-12 and August 17-18, dissolved oxygen determinations were performed every four hours at Stations A, C, H, J, M, and O. The results of these analyses are presented in Figures 5-10. It can be seen that the dissolved oxygen concentration varied considerably during a given 24-hour period with a minimum concentration occurring at about 7:00 a.m. and a maximum concentration occurring at about 7:00 p.m. This diurnal fluctuation of dissolved oxygen concentration is typical of the effect of algae in a stream. Table 8 summarizes maximum, minimum, and average dissolved oxygen concentrations observed during the two 24-hour sampling periods.

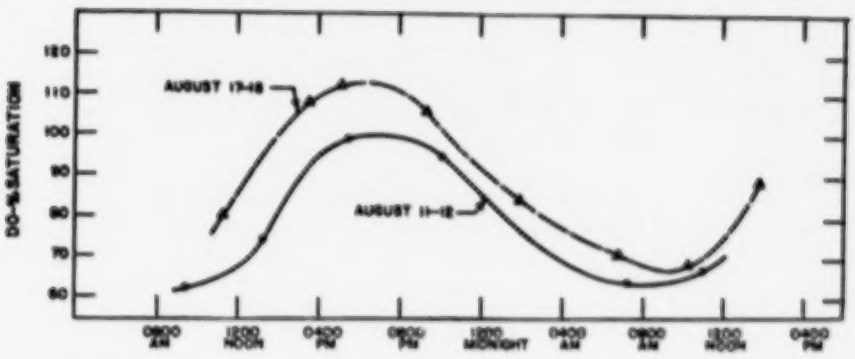
It is evident that the significance of any single dissolved oxygen observation in the stream is greatly affected by the time of day at which the sample is obtained. Flows encountered during the survey were relatively high and fluctuated considerably, resulting in conditions not conducive to the growth of algae. Under conditions of prolonged low-flow it might be expected that hourly dissolved oxygen fluctuations of a magnitude considerably greater than those observed would occur. In addition, occasional abnormally low dissolved oxygen concentrations may occur as the result of unusually high waste discharges or environmental changes which destroy an algal bloom.



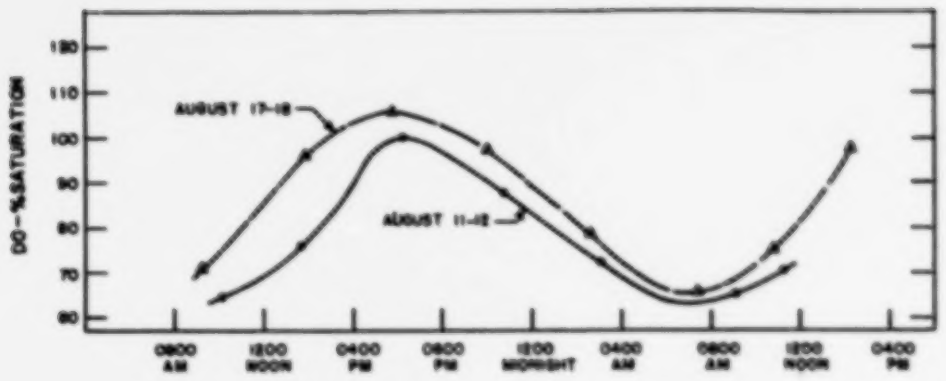
DISSOLVED OXYGEN VS. TIME OF DAY
STATION A
FIGURE 5



DISSOLVED OXYGEN VS. TIME OF DAY
STATION C
FIGURE 6

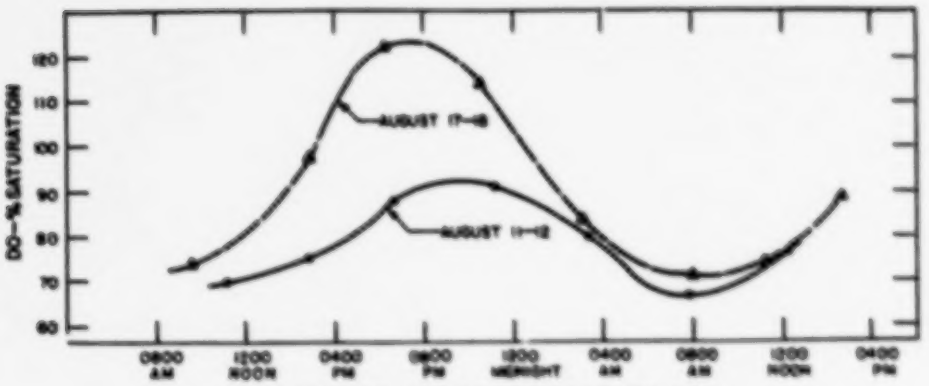


DISSOLVED OXYGEN VS. TIME OF DAY
STATION H
FIGURE 7



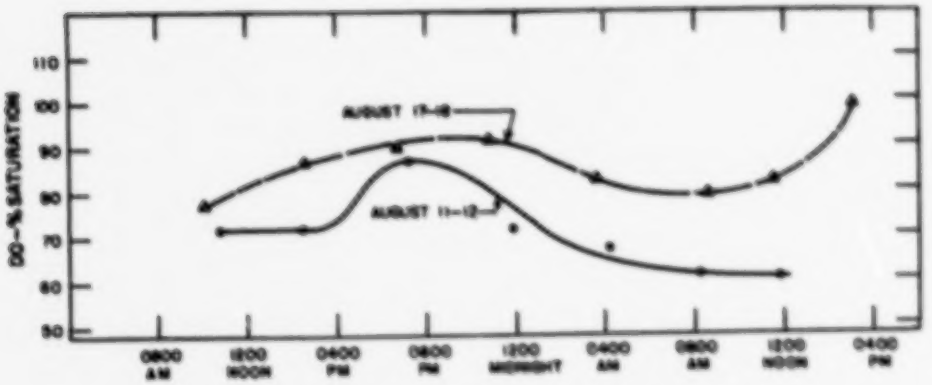
DISSOLVED OXYGEN VS. TIME OF DAY
STATION J

FIGURE 8



DISSOLVED OXYGEN VS. TIME OF DAY
STATION M

FIGURE 9



DISSOLVED OXYGEN VS. TIME OF DAY
STATION O

FIGURE 10

Table 8

Average and Extreme Dissolved Oxygen Concentrations

Station	August 11-12, 1955			August 17-18, 1955		
	Max. D.O. (% Sat.)	Avg. D.O. (% Sat.)	Min. D.O. (% Sat.)	Max. D.O. (% Sat.)	Avg. D.O. (% Sat.)	Min. D.O. (% Sat.)
A	113	92	73	121	92	66
C	106	88	69	121	93	68
E	100	80	64	113	90	67
J	100	79	64	105	87	66
M	92	79	66	123	94	71
O	86	72	61	92	85	79

Stream BOD's observed during the survey were all low, ranging from 1.3 ppm to 5.0 ppm (ultimate), indicating a slightly polluted stream. The long term BOD tests discussed in the next section indicated that a significant fraction of the BOD was relatively old, reflecting the high degree of waste treatment provided.

Observations made during the survey indicated that there was an increase in load between Stations H and M. Based on the 24-hour sampling period on August 11-12, which is believed to most nearly represent steady flow conditions, the stream BOD, expressed in pounds per day, increased somewhat in the reach H-J (1100 lbs/day to 1260 lbs/day) and remained constant in the reach J-M. There are no known sources of pollution below Station H. Considering that BOD is constantly being satisfied in the river, this would indicate an apparent source of BOD in this reach. This discrepancy could conceivably be caused by a waste discharged upstream if the waste had a delayed BOD reaction, i.e., if the BOD in the waste did not begin to be satisfied until some distance downstream from the point of discharge. Some support for this reasoning is found in the fact that there is a definite lag in the BOD rate curve obtained from Station J. (See Fig. 12)

An apparent load increase could also result because of the occurrence of nitrification in some of the 5-day BOD's. As noted below the BOD rate curves generally indicated a second stage beginning on the fourth or fifth day.

Both weeks of sampling were preceded by heavy rains. The resulting increases in discharge may well have resulted in a "flushing" action that washed organic materials into the stream from the watershed and/or scoured material previously deposited on the stream bed, thereby creating an effect similar to that which would result from an additional distributed source of pollution. The available data were insufficient to permit reaching a definite conclusion regarding the reason for the observed increases in BOD. Allowance for this condition was made in the analysis by introducing loads of appropriate magnitude in the reaches H-J and J-M. The magnitude of these loads is discussed in detail on page 29. While these loads were not especially large, their effect was definite.

Long Term BOD Studies

In order to determine deoxygenation rate constants in the river, a series of long term BOD analyses were performed on samples from six sampling stations. Samples were incubated in duplicate in the dark at 20°C, and dissolved oxygen determinations were made after each of the following periods of incubation: 1, 2, 3, 4, 5, 7, 9, 11, 13, and 15 days. Examples of several of the resultant

plots of BOD vs. time of incubation are shown in Figures 11-14. In all of the samples it appears that a second stage BOD, probably nitrification, occurs after the fourth or fifth day of incubation. This is probably a reflection of the high degree of treatment provided all organic wastes discharged to the stream.

At Station J there is a definite lag period of about one day. The BOD determinations on the cyanide waste from Talon, Inc. indicated that this waste might contain an agent that is toxic to the BOD reaction. Several of these samples were run at concentrations ranging from 2% to 5%, and seeded with river water. The lower sample concentration indicated a BOD of 120-130 ppm while the higher concentration indicated a BOD of only 20-30 ppm. If the waste contained toxic substances, dilution from 5% concentration to 2% concentration apparently was sufficient to overcome or reduce the effect of the toxicity. If a sufficient quantity of toxic substance were discharged it could account for the lag observed at Station J. Values of the BOD rate constant, k_1, were obtained from the data, using several methods of calculation. The results obtained indicate that a value of $k_1 = 0.20$ at 20°C was representative of conditions throughout the reach of river studied.

Pollution Source Data

In order to define the condition of a stream, it is imperative to know accurately the magnitudes of all the major loads discharged to the stream. It is also necessary to know the nature and magnitude of any fluctuations in loading that may occur. Load fluctuations will occur even though a high degree of treatment is provided. An increase in raw load entering the treatment works would cause an increase in effluent load, assuming constant treatment efficiency. A decrease in efficiency of treatment caused by mechanical breakdown, careless operation, or factors beyond the control of the operator, could cause considerable fluctuation in load. For example, a decrease in efficiency of treatment from 95% to 90% would double the load discharged to the stream. Accidental or unknown discharges of pollutional material that bypass the treatment works are another possible source of such fluctuations; one such source was discovered during this survey, as noted on the next page.

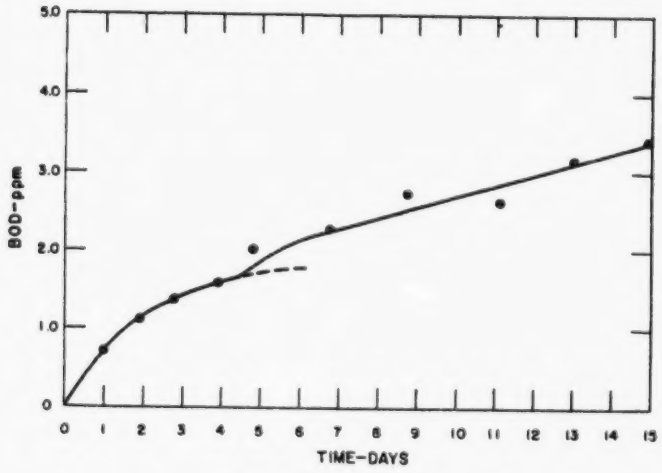
In addition to average present loads, maximum present loads were used in the analysis. The maximum present load was considered to be the maximum load likely to occur under present conditions. This provides for any reasonable fluctuations of effluent loads above the average. In estimating the magnitudes of pollution loads, available operating records of the several plants were used to supplement survey data.

American Viscose Corporation - The principal sources of waste in this plant involve sanitary sewage and the manufacture of acetate flake. The sanitary sewage is treated in an Imhoff tank and then passes to the deep well, where it is mixed with the settled process wastes. The combined waste is then pumped to trickling filters, which are followed by clarifiers. The effluent from the clarifiers is discharged to French Creek through the "Mill Waste Outfall" (lower outfall). This treatment works was designed to treat 3.0 mgd of waste having an average five-day, 20°C BOD of 300 ppm.

The "Mill Waste Outlet" was sampled regularly during the survey (see page 9). Discharge measurements were made at frequent intervals by company personnel and the information made available to the Public Health Service. Discharges during the period of the survey ranged from 1.55 mgd to 2.14 mgd with an average value of 1.78 mgd. BOD values obtained on the waste discharged from this outfall ranged from 0.78 to 2.64 ppm of ultimate first stage BOD with an average value of 1.63 ppm, which indicates a waste load of 24 pounds per day.

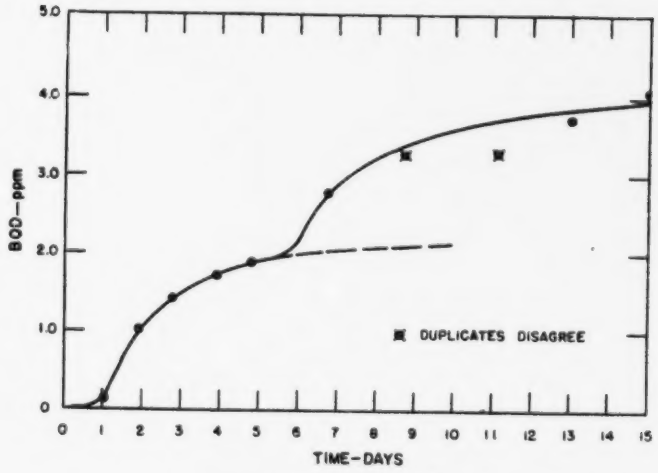
Discharges from the middle outfall normally include roof drainage, cooling water from the powerhouse, and overflow from spray ponds (reused boiler water). Sampling of this outfall indicated an ultimate first stage BOD ranging from 0.73 ppm to 2.38 ppm with an average value of 1.59 ppm. The volume of waste discharged from this outfall was not measured but was quite small.

Discharges from the upper storm sewer (upper outfall) normally include roof drainage, cooling tower overflow, spinning pump cooling water, and condensate from carbon recovery traps. Discharge from the upper outfall was estimated to be about 0.3 mgd. BOD data are not available for this outfall for the first week of the survey (August 8-12), but measurements during the period August 15-19 indicate 5-day 20°C BOD's ranging from 120 ppm to 194 ppm with an average value of 153 ppm. This BOD was considerably greater than would normally be expected from this outfall. Investigation within the plant by company personnel disclosed that the probable source of BOD in the sewer was water coming from leaky traps in the carbon recovery system. This conclusion was confirmed by a grab sample taken by the company on August 16, 1955, which showed 141 ppm acetone. It was estimated that the average load discharged to French Creek by this industry during the survey ranged between 225 and 360 pounds per day ultimate first stage BOD (total, from all sewers). A load of 225 pounds per day ultimate first stage BOD was used for calculating dissolved oxygen profiles for comparison with observed profiles.



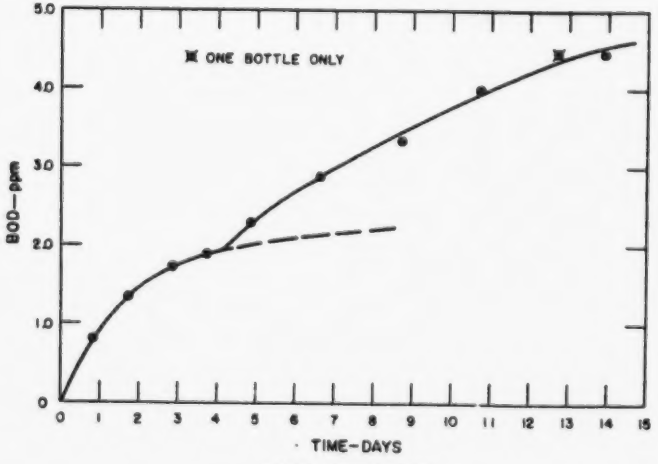
LONG TERM BOD
STATION G—AUGUST 8, 1955

FIGURE 11



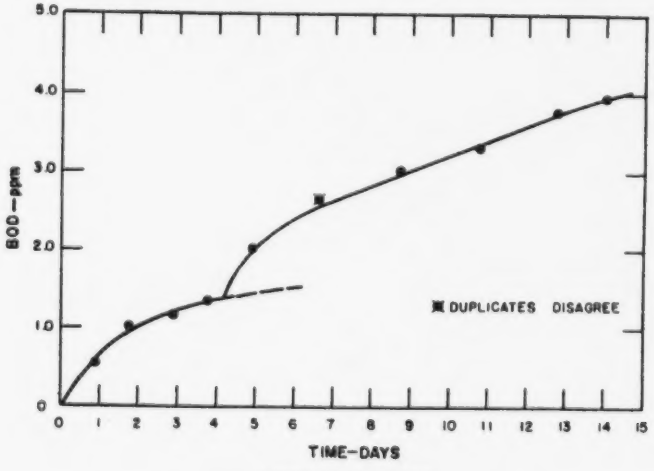
LONG TERM BOD
STATION J—AUGUST 8, 1955

FIGURE 12



LONG TERM BOD
STATION M—AUGUST 9, 1955

FIGURE 13



LONG TERM BOD
STATION O—AUGUST 9, 1955

FIGURE 14

Observed effluent data were considered insufficient for use in determining the average magnitude of loads from this industry. Accordingly, two other methods were employed to establish loads for use in determining low-flow requirements. One method involved the use of design criteria for the treatment plant. The design load on the treatment works is 7,500 pounds per day of 5-day, 20°C BOD. This plant was operating at about 60% of capacity during the survey. Assuming an average of 93% BOD removal for the plant, the BOD discharged to the river would be 315 pounds per day of 5-day BOD [(0.07)(0.60)(7,500)]. To determine the maximum present load which might be discharged to the river, the plant was assumed to be operating at 100% of capacity and the efficiency of BOD removal was assumed to decrease to 90%. Under these conditions the BOD discharged to the river would be 750 pounds per day of 5-day BOD [(0.10)(1.00)(7,500)]. Loads calculated in this manner do not include any BOD discharged from either the upper or middle outfalls. Converted to ultimate first stage BOD, these figures are equivalent to 370 and 880 pounds per day, respectively.

The other method used to supplement observed effluent data consisted of analyzing stream BOD's above and below the plant to determine BOD changes in the river. Twenty matched pairs of samples from Stations A, B, and C were examined. BOD increases in the reaches A-B and A-C ranged from 0 to 2,390 pounds per day ultimate BOD, with an average value of 565 pounds per day and a median value of 450 pounds per day. The median value of 450 pounds per day was judged to be most representative of average conditions since there was a single unusually high result. While the maximum increase in stream load observed was 2,390 pounds per day of ultimate BOD the value exceeded in five out of twenty observations (700 pounds) was judged more representative of the maximum value. The maximum present load (1,150) was obtained by adjusting the BOD increase of 700 pounds per day observed at 60% of capacity to plant operation at 100% of capacity. [(700)(1.00)/(0.60)] These loads, as calculated, are conservative because no attempt was made to account for satisfaction of BOD within the reaches under consideration.

The final choice of loads to be used for prediction of low-flow requirements was based on the method last discussed. The loads are presented in Table 18. (See page 40.)

Talon, Inc. - This industry produces wastes including cyanides and cyanide rinse water from metal plating operations and acids, caustics, biochromates, oils, soaps, etc., from pickling and other metal-finishing processes. Cyanide wastes are batch treated with chlorine and lime, and acid wastes are batch treated with ferrous sulphate and lime. After settling, the supernatant is decanted and discharged to French Creek. The rate of discharge is controlled by flow meters with a maximum rate of discharge of 100 gpm for both treated acid and treated cyanide wastes. Under normal operating conditions treated acid and treated cyanide wastes are discharged together, giving a maximum rate of discharge to the stream of 200 gpm. The sludge from the treatment operation is hauled by tank truck to a lagoon outside the city of Meadville.

Discharges from this plant were sampled by company personnel regularly during the survey and the samples were turned over to the field laboratory for analysis. A complete record of all discharges to French Creek during the period August 8-19 was furnished by the plant. This record includes the plant batch number, the time of discharge, total volume discharged, and the rate of discharge for each batch.

During the survey, normal operation of this plant involved the discharge of one batch daily of treated cyanide waste and three batches daily of treated acid waste. The average volume discharged per batch of cyanide waste was about 24,000 gallons, and the average volume discharged per batch of acid waste was about 40,000 gallons. BOD analyses performed on these wastes indicated that the cyanide waste had an ultimate BOD of about 140 ppm and that the acid waste had an ultimate BOD of about 15 ppm. Therefore, the average BOD load (in pounds per day) discharged to French Creek from this plant would be as follows:

Cyanide: - $\frac{8.34 \times 24{,}000 \times 140}{10^6} \times (1) = 28$ pounds per day

Acid: - $\frac{8.34 \times 40{,}000 \times 15}{10^6} \times (3) = 15$ pounds per day

Total: - 43 pounds per day.

A load of 50 pounds per day ultimate first stage BOD was chosen for use in predicting low-flow requirements. It was not considered necessary to make any adjustments of this load because it is so small and because there is no reason to expect any appreciable future increase.

Sewage Treatment Plant -

City of Meadville, Pennsylvania - During the summer, the City of Meadville Sewage Treatment Plant provides complete treatment (activated sludge) for the sanitary wastes of the city (1950 population 18,972). During the winter months (when flow in the creek is not critical) primary treatment alone is provided.

The effluent from the sewage treatment plant was sampled regularly during the survey. During this period (August 10-18, 1955) the average daily discharge varied from 2.66 mgd to 3.02 mgd with an average value of 2.84 mgd. The discharge from the plant on August 13, 1955 of 4.44 mgd, was not included in the average because the discharge included considerable storm water infiltration and because an undetermined amount of raw sewage was bypassed on this date. The BOD discharged from the plant varied from 7.4 ppm to 31.6 ppm with an average of 15.3 ppm ultimate first stage BOD. Thus, the average daily load discharged to French Creek by the sewage treatment plant was 362 pounds per day. This load was used to compute dissolved oxygen profiles for comparison with observed profiles.

A statistical analysis of daily operating records for the years 1952, 1953, and 1954 indicated a mean effluent BOD of about 450 pounds per day. For use in predicting low-flow requirements an average present load of 425 pounds per day and a maximum present load of 800 pounds per day were selected. The maximum present load selected was the load exceeded on only 7% of the days in the period 1952-1954.

Other Loads - The existence of an apparent load in the reaches H-J and J-M has been mentioned previously (see page 23). Data obtained during the field survey indicated that, at a river discharge of 80 cfs at Meadville, the magnitude of this load was about 450 pounds per day ultimate BOD in each of the reaches H-J and J-M. It must be recognized, however, that there was a period of heavy precipitation immediately preceding the survey and that this might have accounted for a considerable portion of the observed apparent load. The presence of a pronounced lag in the BOD reaction at Station J indicates that some allowance should be made for apparent loads introduced in the reaches H-J and J-M. The following loads were chosen to be applied in the calculation of low-flow requirements:

Discharge at Meadville (cfs)	Ultimate BOD added in each reach (lb/day)
35	125
50	150
75	200

These loads were assumed to enter French Creek midway between Stations H and J and midway between Stations J and M.

Supplementary Analytical Data

Supporting analytical data obtained on stream and industrial waste samples are presented in Tables 9-15. They were used primarily as an aid to interpretation of stream DO and BOD observations. The increases noted in nitrite and nitrate nitrogen and orthophosphate support the observation made earlier that significant algal activity may be expected in French Creek below the City of Meadville.

Table 9

Summary of Analytical Data

Stream Sampling Stations

Station	A	B	C	D	E	F	G	H	I	J	K	L	M	O
pH														
No. of Observations	17	5	19	5	5	5	5	18	4	19	5	5	19	16
Maximum	8.4	8.2	8.4	7.7	8.2	8.0	7.9	9.1	8.0	8.2	8.0	8.0	8.2	8.2
Minimum	7.8	7.9	7.9	7.2	7.7	7.7	7.7	7.7	7.7	7.6	7.7	7.6	7.4	7.6
Average	8.1	8.0	8.1	7.5	7.9	7.8	7.8	8.0	7.8	7.9	7.8	7.8	7.9	7.8
Alkalinity														
No. of Observations	17	5	19	5	5	5	5	5	4	5	5	5	5	2
Maximum	87	90	92	54	85	86	87	81	77	81	80	76	71	55
Minimum	66	70	67	32	57	61	61	61	60	56	56	56	53	49
Average	71	76	72	46	71	71	72	71	68	69	69	66	64	52
Suspended Solids														
No. of Observations	5	5	-	5	-	-	-	5	-	5	-	-	5	2
Maximum	61	69	-	83	-	-	-	40	-	84	-	-	88	26
Minimum	16	17	-	20	-	-	-	16	-	21	-	-	16	24
Average	32	35	-	41	-	-	-	26	-	51	-	-	44	25
NO_3														
No. of Observations	11	-	-	-	-	-	-	10	-	-	-	-	-	-
Maximum	0.15	-	-	-	-	-	-	0.35	-	-	-	-	-	-
Minimum	0.03	-	-	-	-	-	-	0.08	-	-	-	-	-	-
Average	0.08	-	-	-	-	-	-	0.20	-	-	-	-	-	-
NO_2														
No. of Observations	2	-	1	-	-	-	2	2	-	1	-	2	3	3
Maximum	0.0064	-	-	-	-	-	0.0084	0.0380	-	-	-	0.0250	0.0250	0.0140
Minimum	0.0058	-	-	-	-	-	0.0084	0.0184	-	-	-	0.0160	0.0062	0.0084
Average	0.0061	-	0.0024	-	-	-	0.0084	0.0282	-	0.0254	-	0.0205	0.0159	0.0103
PO_4														
No. of Observations	3	-	-	-	-	-	-	3	-	-	-	-	-	-
Maximum	0.010	-	-	-	-	-	-	0.86	-	-	-	-	-	-
Minimum	0.0000	-	-	-	-	-	-	0.61	-	-	-	-	-	-
Average	0.005	-	-	-	-	-	-	0.74	-	-	-	-	-	-
CN														
No. of Observations	1	-	1	-	-	-	-	3	-	-	-	-	-	1
Average	0.01	-	0.01	-	-	-	-	0.01	-	-	-	-	-	0.01

Table 10

Summary of Analytical Data
Sewage Treatment Plant
City of Meadville, Pa.

	Number of Observations	Maximum	Minimum	Average
pH	7	7.4	7.2	7.3
Alkalinity (ppm)	7	206	157	181
NO_3 (ppm)	10	3.0	1.0	1.85
NO_2 (ppm)	11	6.50	0.80	2.17

Note: Average discharge 2.84 mgd.

Table 11

Summary of Analytical Data
Talon, Inc.
Treated Acid Waste

	Number of Observations	Maximum	Minimum	Average
pH	10	10.6	8.4	9.1
Alkalinity (ppm)	10	115	28	52
Chromium (ppm)	9	0.88	0.12	0.32
Copper (ppm)	11	1.80	<0.10	0.61*
Zinc (ppm)	4	0.70	0.11	0.36

* Three observations reported < 0.10 ppm included as being equal to 0.10 ppm.

Table 12

Summary of Analytical Data
Talon, Inc.
Treated Cyanide Waste

	Number of Observations	Maximum	Minimum	Average
pH	3	9.8	8.9	9.4
Alkalinity (ppm)	3	628	131	429
Cyanide (ppm)	4	9.25	< 0.01	4.45*
Chromium (ppm)	3	2.40	0.28	1.49
Copper (ppm)	4	1.80	< 0.10	1.00**
Zinc (ppm)	4	1.20	0.24	0.64

* One observation reported < 0.01 ppm included as being equal to 0.01 ppm.
** One observation reported < 0.10 ppm included as being equal to 0.10 ppm.

Table 13

Summary of Analytical Data
American Viscose Corp.
Upper Outfall

	Number of Observations	Maximum	Minimum	Average
pH	7	8.4	8.1	8.3
Alkalinity (ppm)	5	173	132	143
NO_3 (ppm)	4	0.10	0.00	0.06
PO_4 (ppm)	4	3.20	0.76	1.44

Note: Estimated discharge 0.3 mgd.

Table 14

Summary of Analytical Data
American Viscose Corp.
No. 1 Storm Sewer (Middle Outfall)

	Number of Observations	Maximum	Minimum	Average
pH	7	8.8	8.2	8.4
Alkalinity (ppm)	5	156	116	127
NO_3 (ppm)	4	0.60	0.03	0.21
PO_4	4	8.00	0.60	2.50

Table 15

Summary of Analytical Data
American Viscose Corp.
Mill Waste Outlet (Lower Outfall)

	Number of Observations	Maximum	Minimum	Average
pH	7	8.2	8.1	8.1
Alkalinity	5	136	106	115
NO_3 (ppm)	6	0.40	0.20	0.28
PO_4 (ppm)	4	0.64	0.35	0.49

Note: Average discharge 1.78 mgd.

PREDICTION OF LOW-FLOW REQUIREMENTS

A fundamental objective of this study was to evaluate the ability of French Creek to assimilate pollution loads under critical flow conditions. Flow data for French Creek are available from U. S. Geological Survey records at the following stations:

Station	Drainage Area (Square Miles)	Period of Record
Carter's Corners	208	Oct., 1919 to Sept., 1920 and Aug., 1932 to present
Venango	597	Dec., 1938 to Sept., 1946
Saegertown	629	Oct., 1931 to Sept., 1939
Utica	1,028	Aug., 1932 to present

The drainage area at Meadville below Cussewago Creek (survey Station E) is about 790 square miles. A low-flow frequency analysis has been made using the data shown in Table 16. This analysis indicated that once in five years the minimum daily low-flow at Meadville may be expected to be equal to or less than 41 cfs and once in ten years it may be expected to be equal to or less than 35 cfs. For the purposes of this analysis the critical flow at Meadville was assumed to be 35 cfs.

The analysis of the stream was carried out stepwise, beginning at the upstream end (Station A) and proceeding downstream, taking each reach of the stream separately. In order to proceed with an analysis of this type, two major factors must be determined for each reach. These factors are the oxygen income and the oxygen demand in the reach. Reaeration and reoxygenation incomes were computed by means of the Standard Reoxygenation Curve developed by C. J. Velz.(2)

Table 16

French Creek
Minimum Daily Discharge By Years

Year	Minimum Daily Discharge (cfs) Saegertown	Venango	Utica
1932	36	-	52
1933	40	-	45
1934	24	-	43
1935	24	-	62
1936	28	-	56
1937	48	-	92
1938	80	-	100
1939	48	-	76
1940	61*	59	95
1941	33*	32	65
1942	37*	36	66
1943	67*	64	111
1944	49*	47	77
1945	69*	66	98
1946	56*	54	54
1947	-	-	83
1948	-	-	90
1949	-	-	101

* Computed from flows at Venango on basis of drainage areas.

Oxygen demand or BOD satisfied was computed by means of a graphical integration of the following formulation:

$$\frac{L_t}{L} = 10^{-k_1 t}$$

where L is the BOD at time zero and L_t is the corresponding value at "t." The zero time is arbitrary and may represent any desired time during the course of the reaction, not necessarily its actual beginning. The graphical integration of pollution loads involves plotting ultimate BOD loads in pounds vs. time of flow in days on semi-log paper.(3) The cumulative BOD load "satisfied" is calculated graphically by drawing a line through the BOD loads at a slope corresponding to the selected value of k_1. Pollution loads are introduced at the points of their entry into the stream and from the resulting graphical integration of pollution loads the BOD remaining in the stream at any point may be read directly. Once satisfactory methods have been established by means of which oxygen income and oxygen demands can be determined, an oxygen balance may be performed on each reach of the river.

Calculations of the natural self-purification capacity of French Creek were first tested against the observed dissolved oxygen profile obtained during the 24-hour sampling run on August 11-12, 1955. This period was chosen because it most nearly represented a steady flow condition and because the 24-hour data permitted a reasonably accurate estimate of daily average dissolved oxygen concentrations and stream BOD values. A value of 0.20 (at 20°C) for the first stage deoxygenation rate constant, k_1, was chosen as described on page 25. Once agreement between the calculated and observed profiles was obtained, it was possible to predict future conditions.

The pollution loads used for calculating the dissolved oxygen profile for comparison with the observed profile were the loads observed during the field survey. These loads are as follows:

American Viscose Corp. - 225 pounds per day ultimate BOD

Talon, Inc. - 50 " " " " "

Sewage Treatment Plant - 360 " " " " "

In accordance with survey data, inflow from Cussewago Creek was assumed to contain 5.6 ppm dissolved oxygen and 3.4 ppm ultimate first stage BOD. Similarly, at Station A the residual was assumed to be 1.9 ppm ultimate first stage BOD and the dissolved oxygen concentration was assumed to be 91% of saturation. A river

temperature of 26°C which approximated the average temperature encountered during the 24-hour sampling run of August 11-12, 1955 was used in this calculation. A comparison of calculated and observed dissolved oxygen profiles may be found in Table 17.

The analysis covered only the reach between Stations A and M. In every calculation performed, even those employing anticipated future loads, minimum dissolved oxygen concentrations occurred in the reach I-J. The stream appears to be well into the zone of recovery by Station M.

The methods of determining loads for use in the prediction of low-flow requirements have been discussed previously. A summary of the loads thus determined is presented in Table 18. In addition to the loads presented in Table 18, loads were introduced in the reaches H-J and J-M, as a result of the apparent loads observed in those reaches during the survey as noted on page 29.

Residual stream BOD at Station A was assumed constant at 1.9 ppm (ultimate). Analysis of stream BOD data indicated that the BOD, expressed in pounds per day, was related to stream discharge, with an increase in discharge resulting in an increase in BOD. The concentration of BOD remained more or less constant, and dilution with increasing flow had a relatively minor effect. This effect is not uncommon in streams having low BOD. At discharges greater than 100 cfs this relationship fails, but for the range of discharges under consideration (35-75 cfs) it was considered most nearly representative to assume a constant BOD concentration.

A summary of assumed stream conditions in French Creek and Cussewago Creek for low-flow analysis is presented in Table 19.

Table 17

Comparison of Calculated and Observed Dissolved Oxygen Profiles

Station	Observed DO (% saturation)	Calculated DO (% saturation)
A	91	91
B	89	90
Cussewago Cr. (above)	86	88
Cussewago Cr. (below)	83	84
F	83	84
G	82	84
H	82	83
I	80	82
J	80	81
K	79	82
L	79	85
M	79	83

Table 18

Ultimate BOD Loads (Pounds Per Day) Used For Prediction of Low-Flow Requirements

	Avg. Present Load	Max. Present Load	Max. Present Load (With 25% Growth)	Max. Present Load (With 50% Growth)
American Viscose Corporation	450	1,150	1,440	1,725
Talon, Inc.	50	50	50	50
Sewage Treatment Plant	425	800	1,000	1,200

Table 19

Summary of Assumed Stream Conditions for Low-Flow Analysis

French Creek						Cussewago Creek				
Station E	Station A					Station D				
Q_E	Q_A*	Ultimate BOD		Dissolved Oxygen**		Q_D*	Ultimate BOD		Dissolved Oxygen	
(cfs)	(cfs)	(ppm)	(lb/day)	(ppm)	(lb/day)	(cfs)	(ppm)	(lb/day)	(ppm)	(lb/day)
35	30.1	1.9	310	7.2	1,170	4.9	3.4	90	5.6	148
50	43.0	1.9	440	7.2	1,670	7.0	3.4	128	5.6	211
75	64.5	1.9	660	7.2	2,500	10.5	3.4	192	5.6	317

* Computed from the discharge at Station E.

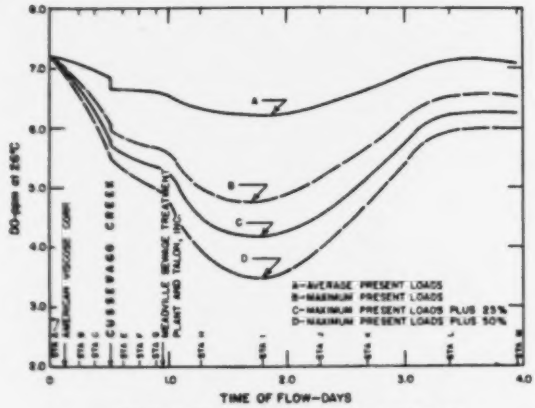
** Assumed deficit of 1.0 ppm and assumed temperature of 26°C gives dissolved oxygen concentration of 7.2 ppm.

Low flow augmentation requirements have been based on maintaining an average daily dissolved oxygen concentration of 5.0 ppm in the stream at the critical point. Dissolved oxygen concentrations below 5.0 ppm will occur with the recommended flows and under the assumed loading conditions as the result of diurnal fluctuations, rather than excessive pollution loadings. It is not expected that fluctuations of this nature will be of sufficient magnitude or duration to adversely affect aquatic life.

Daily average dissolved oxygen profiles computed in accordance with the foregoing considerations are presented in Figures 15-17. These computations were carried out at flows of 35 cfs, 50 cfs, and 75 cfs at Meadville (Station E). The average present load determined during this survey resulted in critical dissolved oxygen concentrations of 6.2 ppm at 35 cfs and 6.3 ppm at 50 cfs. The assumed maximum present loads resulted in critical dissolved oxygen concentrations of 4.8 ppm at 35 cfs and 5.2 ppm at 50 cfs. Thus, under present conditions, a minimum flow of between 35 and 40 cfs should be adequate to provide a daily average dissolved oxygen concentration of 5.0 ppm in the stream at all times. As has been mentioned previously, a daily low-flow of 35 cfs or lower may be expected to occur only once in ten years, so it may be assumed that in nine out of ten years there would be virtually no question of maintaining a daily average dissolved oxygen concentration of 5.0 ppm in the stream.

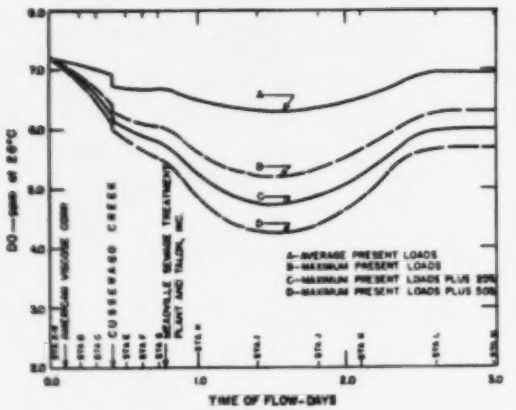
For purposes of predicting possible future conditions the maximum present load from each source was increased 25% and 50% to allow for possible industrial expansion and population increases. Estimated maximum present loads increased 25% to allow for future expansion result in critical dissolved oxygen concentrations of 4.2 ppm at 35 cfs, 4.7 ppm at 50 cfs and 5.5 ppm at 75 cfs. Under these loading conditions it is estimated that a flow of 60 cfs would be required to maintain a daily average dissolved oxygen concentration of 5.0 ppm in the river. Increasing the estimated maximum present loads 50%, to allow for future expansion, results in daily average dissolved oxygen concentrations at the critical point of 3.5 ppm at 35 cfs, 4.3 ppm at 50 cfs, and 5.2 ppm at 75 cfs. Under these loading conditions it is estimated that a flow of 70 cfs would be required to maintain a daily average dissolved oxygen concentration of 5.0 ppm in the river.

A summary of this low-flow analysis is presented in Table 20.



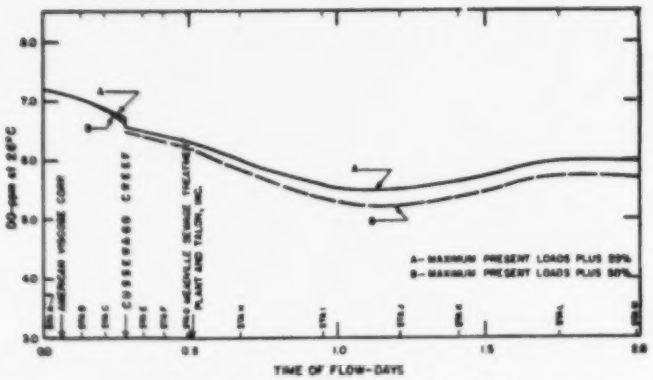
CALCULATED DISSOLVED OXYGEN PROFILES
Q_E = 35cfs

FIGURE 15



CALCULATED DISSOLVED OXYGEN PROFILES
Q_E = 50cfs

FIGURE 16


DO-ppm at 25°C
TIME OF FLOW-DAYS
A- MAXIMUM PRESENT LOADS PLUS 25%
B- MAXIMUM PRESENT LOADS PLUS 50%
AMERICAN VISCOSE CORP.
CUSSEWAGO CREEK
MEADVILLE SEWAGE TREATMENT PLANT AND TALON, INC.

CALCULATED DISSOLVED OXYGEN PROFILES
Q_E = 75cfs

FIGURE 17

Table 20

Summary of Low-Flow Requirements

Loading	Q* Discharge at Meadville (cfs)	Minimum DO** (ppm)	Estimated discharge required to maintain a minimum critical DO of 5.0 ppm (cfs)
Average Present	35	6.2	
	50	6.3	35
Maximum Present	35	4.8	
	50	5.2	40
Maximum Present	35	4.2	
Plus 25%	50	4.7	60
	75	5.5	
Maximum Present	35	3.5	
Plus 50%	50	4.3	70
	75	5.2	

* Mead Avenue Bridge

** Average daily value

It should be recognized that these conclusions regarding minimum low-flow requirements are based on maximum loadings. These loadings are designed to take into account conditions of treatment plant operation and waste discharges that would result in loads considerably higher than would be the case under average conditions. Conclusions regarding critical stream conditions must of necessity be founded upon critical loading conditions.

These conclusions are based on daily average dissolved oxygen concentrations. The effect of diurnal fluctuations has been discussed and should be recognized. It is to be expected that dissolved oxygen concentrations below 5.0 ppm will occur occasionally with the recommended flows and under the assumed conditions of loading. However, such concentrations would be the result of diurnal fluctuations coupled with maximum waste load conditions rather than excessive pollution loadings. It is not

likely that minimum dissolved oxygen concentrations will occur for a sufficient length of time to adversely affect aquatic life.

A water temperature of 26°C was assumed in the calculations. Higher temperatures under critical flow conditions might result in a decrease in the critical dissolved oxygen concentration but it is believed that, within reasonable limits of temperature change, the effect on the minimum flow requirements would be slight.

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